Peculiarities of Autobalanced Ramsey Spectroscopy of CPT Resonance in Optically Dense Medium

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One of the promising types of microwave frequency standards is standard based on coherent population trapping (CPT) resonance as in cold atomic ensembles [1] as well in hot atoms in a gas cell [2]. The light shift of the etalon transition can degrade stability of the frequency standard because the fluctuations of various parameters such as intensity, phase of the laser radiation, etc. lead to the fluctuations of the reference resonance position. One of the most robust is autobalanced Ramsey scheme [3] that suppresses the light shift caused by intensity fluctuations. But this scheme gives the shift of CPT resonance if the lifetime of the low frequency atomic coherence is comparable to dark periods. Method of combined error signals [4] uses normalization coefficient that compensates this shift and equalizes the amplitudes of the signals of long and short dark periods if the pulse amplitudes stay the same in atomic ensemble. If in the experiment the signal of transmitted radiation is detected, it is necessary to take into account absorption of the pulses and phase incursion. These effects lead to additional shifts of the error signal because the amplitudes of the signals for long and short dark periods become different. It is possible to minimize negative effects of optically dense medium by modification of autobalanced and CES methods, that is the goal of this work.

In our work, we investigate CPT resonance in atomic ensemble with finite optical thickness detected by autobalanced method for microwave atomic clocks. We analyze light shifts of the CPT resonance which appear due to finite lifetime of the low frequency atomic coherence and absorption of the reading pulse in an optically dense medium. It is shown that in optically thin medium the shift of error signal does not depend on fluctuations of total intensity. We compare autobalanced and combined error signal (CES) methods. In optically thin medium CES method allows us to fully suppress light shift, but in optically dense medium it has the shift due to different absorption of the Ramsey sequences with short and long dark periods. It was found that by variation the normalization coefficient of the CES method it is possible to minimize the light shift of the CPT resonance in the ensemble with certain optical thickness. Also, it allows us to minimize the sensitivity to fluctuations of temperature and/or number of atoms.

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References

[1] F-X Esnault, E Blanshan, E N Ivanov, R E Scholten, J Kitching and E A Donley, Phys. Rev. A **88**, 042120 (2013)

[2] M Abdel Hafiz, G Coget, M Petersen, C E Calosso, S Guérandel, E de Clercq and R Boudot, Appl. Phys. Lett. **112**, 244102 (2018)

[3] C Sanner, N Huntemann, R Lange, C Tamm and E Peik, Phys. Rev. Lett. **120**, 053602 (2018)

[4] V I Yudin, A V Taichenachev, M Yu Basalaev, T Zanon-Willette, T E Mehlstäubler, R Boudot, J W Pollock, M Shuker, E A Donley and J Kitching, New J. Phys. **20**, 123016 (2018)